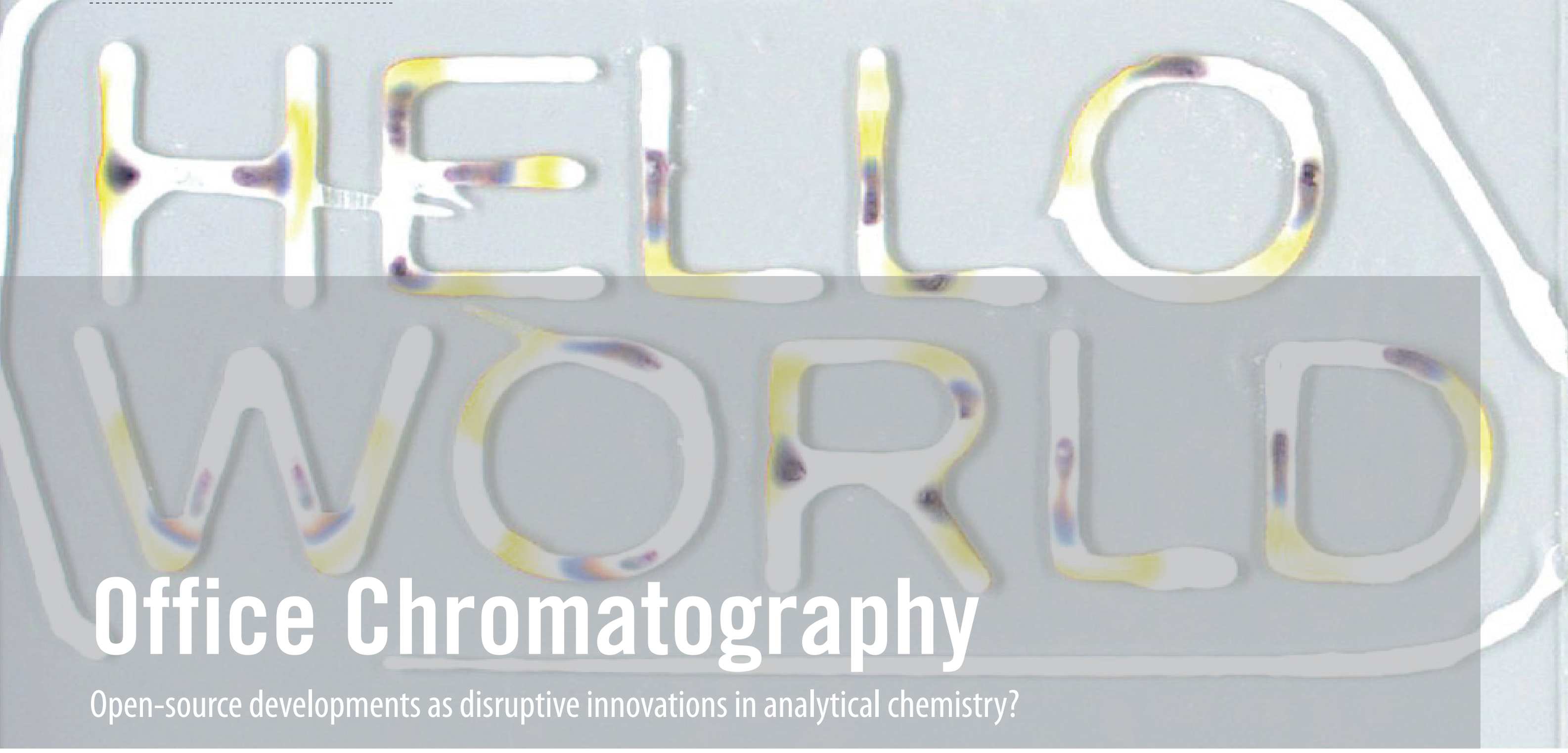

Office Chromatography

Open-source developments as disruptive innovations in analytical chemistry?

Dimitri Fichou | Prof. Dr. Gertrud Morlock

For open-source developments, the redistribution is free, the source code is available and modifications of the device are possible, if the open-source aspect is respected. Thinking about open-source developments, software comes first in mind, but there are several examples of open-source hardware (OSH), *e. g.* the Arduino microcontroller and 3D printers.

Thinking about open-source developments, software comes first in mind, but there are several examples of open-source hardware (OSH), *e. g.* the Arduino microcontroller and 3D printers. Such tools allow the researcher to investigate new technologies in a rapid and cost-effective way. Only a limited knowledge on electronics, mechanics and programming is needed, letting still space to focus on their special field of interest.

Instrument architecture

No matter of the specific field of analytical chemistry, the device used to perform the analysis could be considered as a robot composed of several parts: (1) the mechanical body, (2) the electronics, (3) the microcontroller, (4) the firmware, (5) the control software. The mechanical body holds everything together, and if applicable, supports moving parts. The electronics consists of sensors, heated parts, fans, pumps and motors that communicate with the microcontroller. The control software manages the analysis by sending and receiving signals to the microcontroller that are interpreted by the firmware. 3D printers and in particular the Reprap 3D printer that are self-replicable devices able to reproduce their own parts, are a great inspiration for analytical chemists willing to start building their own apparatus. The main function of the 3D printer is to rapidly produce customized parts that can be installed in a modified prototype or lab device. The open-source aspect of the Reprap 3D printer makes this tool highly customizable through modifications. The microcontroller already permits the control of numerous electronics useful for the analysis and if a new one is needed, it can be implemented easily along the other functionalities that are already present.

For the 3D printer, signals sent from the control software to the microcontroller are named GCODE. They follow a well-known standard that is well adapted to be used for OSH in analytical chemistry, as most of the expected features are already implemented. However, knowledge on a programming language is essential for generating the GCODE files. An alternative is to work with Instrumentino [1], an open-source modular Python framework for controlling Arduino based experimental instruments. In addition to communicating with the Arduino, this option also permits to communicate with third party instruments via application programming interfaces.

Open-source solutions, both hard- and software, come along with a steep learning curve. During the self-assembly of the Reprap 3D printer sold as kit, the user will build valuable skills for trouble shooting and modification. Furthermore, the presence of a strong community of volunteers, answering questions on different forums, constitutes a valuable alternative to the customer support encountered in classic business models.

Office Chromatography

The potential of OSH and 3D printing is exploited for Office Chromatography, a concept combining all steps of miniaturized planar chromatography in the same device [2]. 3D printing consists in the additive application of a layer of materials on a plane surface. *Per se,* planar chromatography has such a plane format, but instead of layers of materials for manufacturing, chemicals have to be applied. The fabrication of thin silica gel layers for

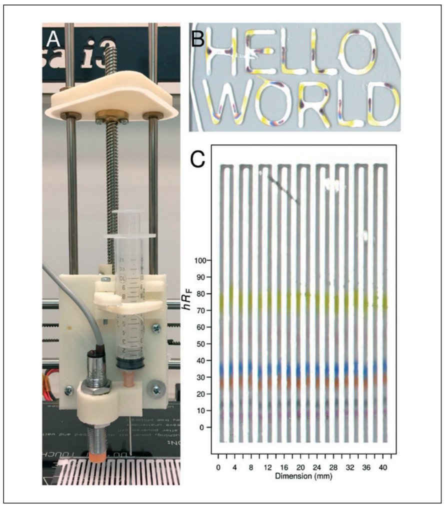

Figure 1. (A) Self-3D printed slurry doser, (B) "Hello world" showing the versatility of patterns and (C) lipophilic dye mixture separated on a channeled plate printed by the apparatus. Reprinted with permission from [3]. Copyright 2017 American Chemical Society.

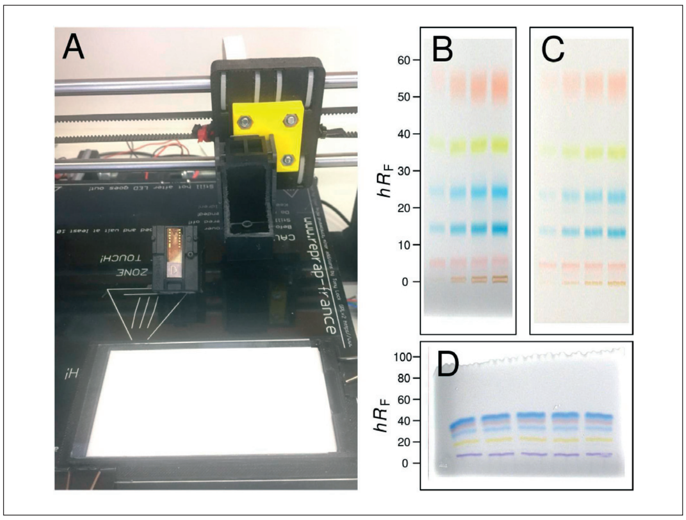

Figure 2. (A) Inkjet cartridge and plate holder mounted on the 3D printer used for analysis of a water-soluble dye mixture on RP18-W phase (B) applied via spray-on application versus (C) printed via inkjet technology; (D) not only the sample solution, but also the mobile phase mixture for separation was printed via the inkjet technology implemented in a 3D printer. Reprinted with permission from [3]. Copyright 2017 American Chemical Society.

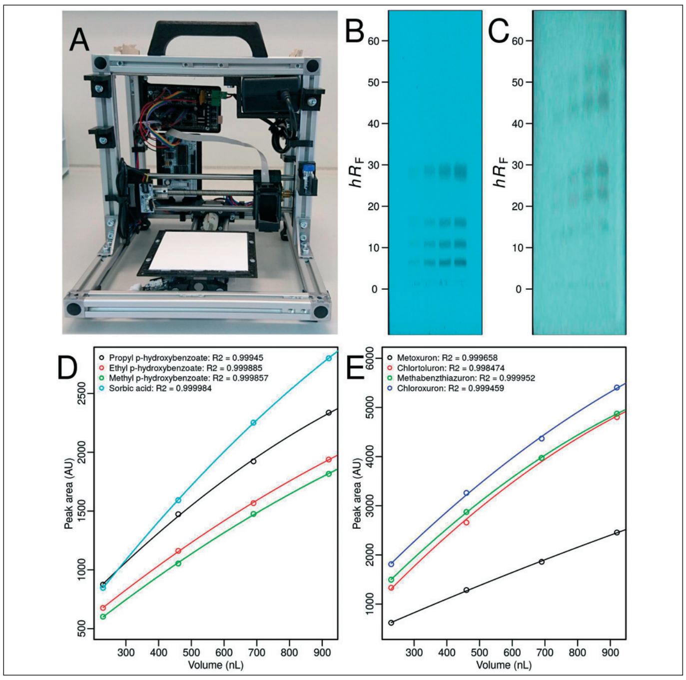

Figure 3. (A) Performance of the inkjet printing via the developed Office Chromatography apparatus: HPTLC chromatogram and calibration curves for (B and D) preservatives and (C and E) pesticides.

planar chromatography using a modified 3D printer has been demonstrated recently [3]. Not only the modified apparatus was affordable in terms of investment costs and advantageous in operation time, but also it opened new perspectives for layer materials and patterns (Fig. 1).

The next steps integrated in Office Chromatography are sample application, development and derivatization. All those steps can be managed by an inkjet print head, and first approaches were focused on modified thermal inkjet printers. For printing of samples and reagents in the analytical laboratory, empty ink cartridges were filled with the solution to be applied [4, 5]. The later use of InkShield, an open-source PCB board supervised by an Arduino, allowed using inkjet technology without relying on the original proprietary hardware. Its integration in a 3D printer environment had already been taken care of, and minimal adaptations of the firmware code were sufficient to use it for analytical chemistry (Fig. 2).

The implementation of a dedicated hardware was a next step. It had been designed in OpenSCAD and most of its complex parts were 3D printed (Fig. 3A). A control software was developed to create GCODE files to send them to the printer. Preservatives and pesticides were applied with this apparatus and showed good linearities (Fig. 3 B-E). The resulting apparatus was affordable (2000 Euro), compact (26 x 31 x 26 cm) and the drop-volume was small (100 pL).

Conclusion

The expansion of OSH is expected to trigger tremendous progress in the field of analytical chemistry, allowing small teams of experts to be as efficient as an entire department in a multinational company. The viral aspect of open-source developments was outlined, giving to the scientific community affordable and innovative tools to be included in their laboratories. The developed Office Chromatography device for ultra-thin layer chromatographic separations will generate progress with regard to novel plate developments as well as fast and economic applications. Open-source developments are similar to radical chain reactions, exponential in progress and highly dynamic in its result. So it is in many aspects an interesting experiment worth to contribute!

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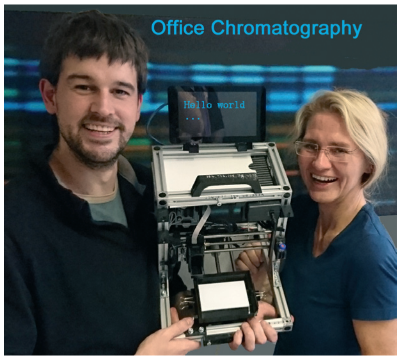

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